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(54) Pneumatic radial tire

(57) A pneumatic tire comprises a radial carcass (1), a belt (3) with crossing cords at 60°-80° to radial planes, tread rubber (7), and, at each side, a bead core (2), a rubber bead filler (F), a base rubber layer (10) which is disposed beneath a joint (9) between a sidewall rubber (6) and the tread rubber (7) and which has a resilience higher than those of the tread rubber and the side wall rubber, and a stress relieving groove (11) provided near the joint (9). The groove (11) may be such that a line (J) bisecting it is inclined to the normal (N-N) by at most 70° and may have a depth of 25-50% (h). The rubber of layer (10) may have a resilience of 60-85% and a loss modulus of elasticity of 2-12 kg/cm². The filler (F) may have a dynamic modulus of 300-1500 kg/cm². The layer (10) may locate beneath the adjacent belt edge, or may be superposed thereon as shown, in which case it may be extended to join the layer at the other side of the tyre.

FIG. 1

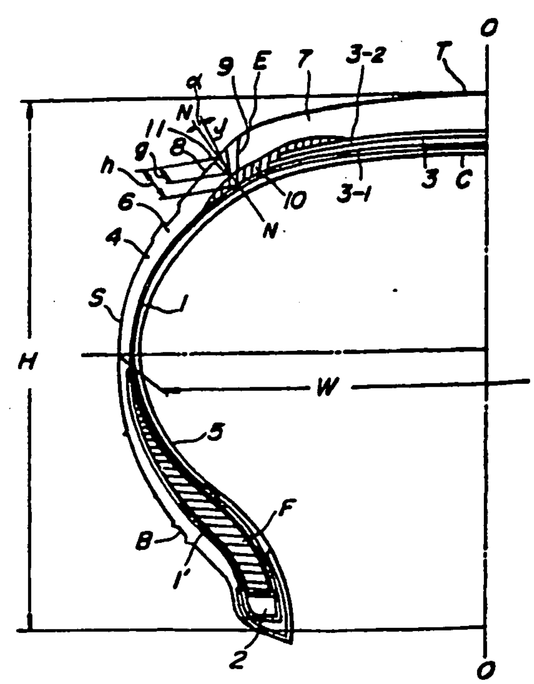


FIG.2

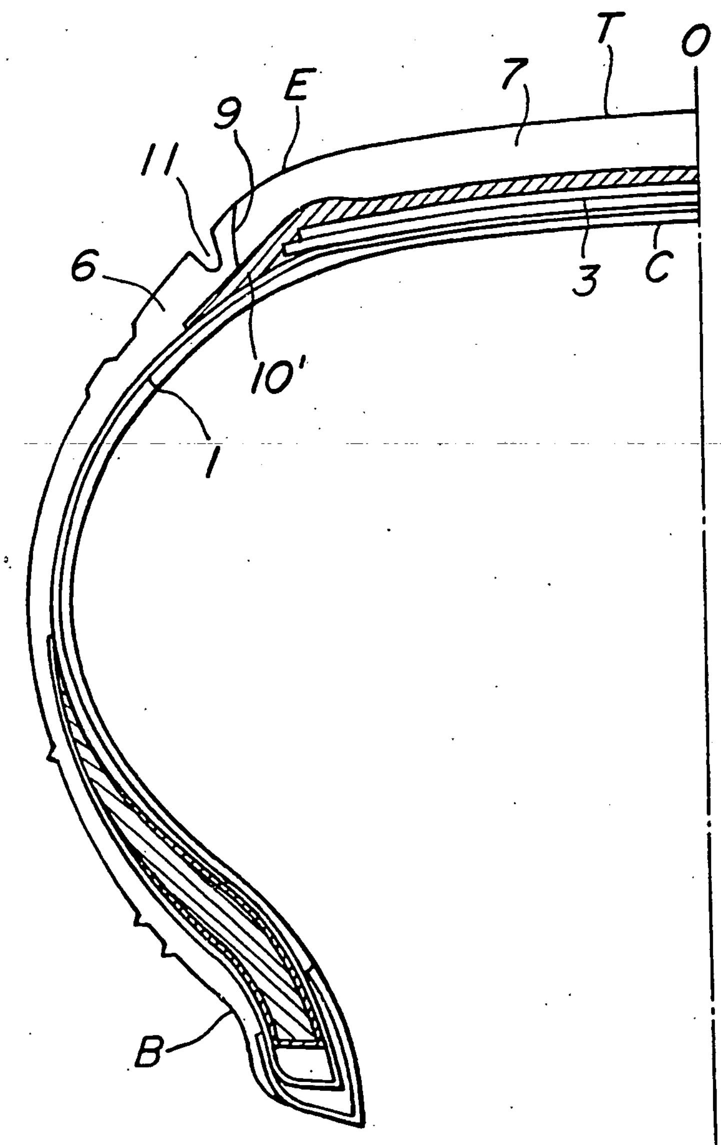
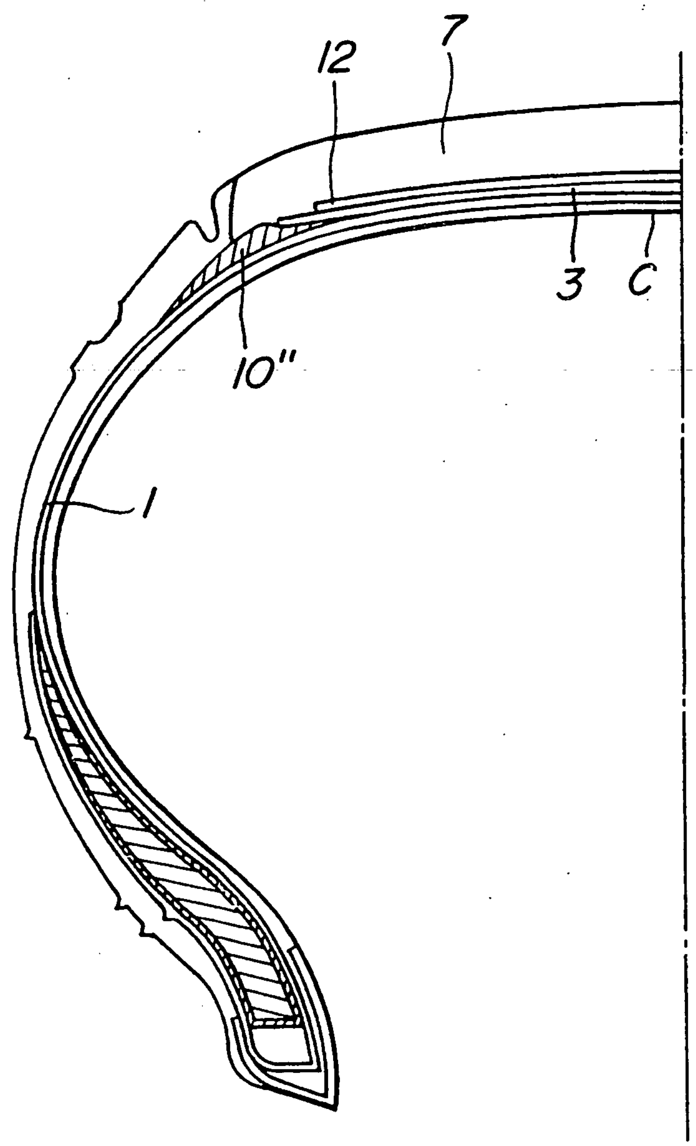


FIG.3



SPECIFICATION

Pneumatic radial tir

This invention relates to a pneumatic radial tire having a reduced rolling resistance, which is particularly suitable for a passenger car.

In general, a radial tire comprises a carcass body which consists of a toroidal carcass composed of plies including radially arranged cords, that is cords arranged in a radial plane inclusive of the rotational axis of the tire or in a plane inclined at a small angle with respect to the radial plane and crossed therewith, and a plurality of belt layers superimposed about the crown portion of the carcass and including cords inclined at an angle of from 60° to 80° to the radial plane of the tire, the cords of adjacent belt layers being crossed with each other, and bead reinforcements each of which consists of the respective end portion of the toroidal carcass wound around a bead core to form a turn-up portion. The carcass body and bead reinforcements are covered with an outer rubber layer and the side portions of the tire are made integral with the bead portions by vulcanization.

The rolling resistance of the tire produced when a vehicle provided with the above-mentioned radial tire runs on a flat paved road without inclination is produced mainly due to the internal loss caused by flexure of the tire during rotation thereof and the frictional loss between the tire and the road surface. In this case, the fact that the rate of the internal loss comprised by the above two losses is large is well known in the art. Many attempts have been made to use a material having a relatively low loss modulus of elasticity as the rubber for all parts of the tire exclusive of the cords.

However, the tire must display different abilities in respect of the different parts such as the tread portion and side portions. As a result, if a rubber having a low loss modulus of elasticity is applied to the tread portion, the frictional coefficient with the road surface is considerably decreased to adversely affect the anti skid property and breaking property, thereby reducing the safety of the tire.

U.S. Patent Specification No. 3 253 635 describes reducing the rolling resistance of a tire by means of an annular groove arranged in the outer rubber layer of the shoulder of the tire and circumferentially extending along the tire. This annular groove is operative to interrupt the tread portion and the side portion which are different from each other in operation as an oscillatory system of the tire when it runs. Such a tire, however, is similar in construction to a tire including a so-called nibbling groove which is well known in the art and displays little effect of reducing the rolling resistance. A tire including a nibbling groove is a tire which is provided at its shoulder portion with a deep annular groove circumferentially extending along the tire and operative to easily transversely deform the tread portion side edge for the purpose of reducing the resistance that trends to be produced when the tire rides over the lengthwise direction of projections slightly raised from the road surface, such as a rail for a street car provided along the road.

The rolling resistance of a tire exerts a direct influence upon the driving force of an automobile, so that it is highly desirable to considerably reduce the rolling resistance of the tire in compliance with the requirements of energy economy.

The present invention provides a pneumatic radial tire, comprising a toroidal carcass including radially arranged cords, a belt layer superimposed about the crown portion of the carcass and including a plurality of cord layers, each cord being inclined at an angle of from 60° to 80° with respect to the radial plane of the tire and the cords of adjacent cord layers being crossed with each other, a pair of bead cores around which the ends of the toroidal carcass are wound to form turn-up portions, a side rubber outwardly covering each side portion and bead portion of the toroidal carcass, a tread rubber outwardly covering the crown portion of the carcas inclusive of the belt layer and forming a joint portion with each side rubber, relatively thin base rubber disposed directly below each joint portion between the side rubber and the tread rubber and superimposed about the outer surface of the carcass and made integral therewith, the said base rubber having a resilience which is higher than those of the tread rubber and side rubb r, and a rubber filler at each bead core disposed between the carcass and its turn-up portion, wherein a stress relieving groove composed of a depression is provided at a position near each joint portion between the side rubber and the tread rubber.

The invention will be further described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a diagrammatic sectional view of the left-half of one embodiment of a pneumatic radial tir according to the present invention;

Figure 2 is a diagrammatic sectional view of the left-half of another embodiment of a pneumatic radial tire according to the present invention; and

Figure 3 is a diagrammatic sectional view of the left-half of a further embodiment of a

The tire shown in Fig. 1 comprises a tread T located at the centre portion thereof and a side portion S projecting outwardly from each of the two side edges E of the tread T. Fig. 1 shows the left-half of the tire for ease of illustration, but it is a matter of course that the tire is symmetrical with respect to the equatorial line O–O. The tire is reinforced by a toroidal carcass 1 composed of plies formed of textile cords such as polyester, nylon or rayon and arranged in a radial plane of the tire, that is a plane perpendicular or substantially perpendicular to the equatorial line O–O. The lower end of the toroidal carcass 1 is wound around a bead core 2 from the inside toward the outside thereof to form a turn-up portion 1′. Fig. 1 shows the carcass 1 composed of one ply only, but the carcass may be composed of two or more plies in dependence on the kind of cords and the use of the tire.

Between the carcass 1 and its turn-up portion 1′ is interposed a rubber filler F extending upwardly from the bead wire 2 to substantially the centre of the side portion S in a conventional manner. In the present embodiment, the rubber filler F is formed of a rubber having a high dynamic modulus of elasticity the value of which preferably lies within a range of from 300 kg/cm² to 1,500 kg/cm².

The composition of the rubber having the above-mentioned modulus of elasticity is as follows. 100 Parts by weight of a vulcanizable rubber selected from natural rubber, diene rubber, diene copolymer rubber and a blend rubber containing such a rubber in any ratio is compounded with 5 to 30 parts by weight, preferably 8 to 30 parts by weight, more preferably 15 to 25 parts by weight, of thermo-setting resin and with 0.5 to 5 parts by weight of a hardening agent for the thermo-setting resin, for example hexamethylene tetramine. If necessary, a reinforcing material, filling agent, anti-ageing agent, vulcanization accelerating agent, activating agent, softening agent, plasticizer, and/or adhesive agent used as a conventional rubber compounding agent other than the above-mentioned compounding agents may be suitably compounded with the above-mentioned rubber.

The thermo-setting resin may be suitably phenol resin, cresol resin,or denatured resin denatured in any ratio of the above-mentioned resins, for example cashew denatured phenol resin, cashew denatured cresol resin, cresol denatured phenol resin, oil denatured phenol or cresol resin denatured with an oil such as linolic acid, linolenic acid, or oleic acid, or an alkyl benzene denatured phenol or cresol resin denatured with an alkyl benzene such as xylene or mesitylene, or phenol or cresol resin denatured with a rubber such as nitrile rubber.

The crown portion C of the toroidal carcass 1 is reinforced by a belt layer 3 superimposed thereon and extending over substantially the total width of the tread portion T. The belt layer 3 is composed of cord layers 3–1 and 3–2 formed of metal cords, or textile cords having a high modulus of elasticity, and inclined at an angle within a range of from 60° to 80° with respect to the radial plane of the tire, these cord layers 3–1 and 3–2 being superimposed one upon the other such that the cords of the cord layer 3–1 are crossed with the cords of the cord layer 3–2 through the equatorial line O–O of the tire. The belt layer may be made of three or more cord layers superimposed one upon the other. Alternatively, ply end portions may be folded to reinforce the end portions of the belt layer.

The total peripheral surface of the carcass 1 is covered at its outside with an outer rubber layer 4 and at its inside with an inner liner 5.

The outer rubber layer 4 is divided into a side rubber 6 having an excellent fatigue resistant property against extensible strain repeatedly applied to the side portion S when the tire runs and a tread rubber 7 having an excellent wear resistant and anti-skid property and located at the tread portion T. The side rubber 6 is made integral with the tread rubber 7 at a joint portion 9 located at a shoulder 8 slightly outside the side edge E of the tread portion T.

The tread portion T is provided with ribs or blocks (not shown) which are divided by means of various kinds of tread grooves, a skid base having a given gauge being provided near the belt layer 3 in a conventional manner.

A relatively thin base rubber 10 is arranged directly below the joint portion 9 and superimposed about and made integral with the outer surface of the toroidal carcass 1 and belt layer 3. The base rubber 10 has a resilience which is higher than those of the side rubber 6 and tread rubber 7.

The side rubber 6 is provided at a position near the joint portion 9 with the tread rubber 7 with a stress relieving groove 11 depressed toward the base rubber 10.

The base rubber 10 is made thinner than the side rubber 6 and tread rubber 7 and the side edge facing the bead portion B is mad wedge shaped and interposed betw en the side rubber 6 and the carcass 1. The base rubber 10 has a centre portion between the tread rubber 7 and th carcass 1 and the side edge facing the crown centre is also made wedge shaped and interposed between the tr ad rubber 7 and belt layer 3.

It is preferably that the base rubber 10 has a higher resilience than those of the adjacent side rubber 6 and tread rubber 7, preferably within a range of from 60% to 85%. In addition, the base rubber 10 preferably has a loss modulus of elasticity of 2.0 to 12 kg/cm².

The stress relieving groove 11 is made V-shaped in section and its base is rounded and is

arranged such that it is depressed toward the base rubber 10 at a position near the joint portion 9 between the side rubber 6 and the tread rubber 7. More particularly, one sidewall of the stress relieving groove 11 is located near the joint portion 9 and the base of the stress relieving groove 11 is spaced apart from the base rubber 10 by a thin layer of the side rubber 6.

In the embodiment shown in Fig. 1, a centre line of the stress relieving groove 11, that is a straight line J bisecting the angle formed between the opposed groove sidewalls, is inclined at an angle α with respect to a normal line N–N which intersects the centre line J at the groove base and inclined toward the crown portion of the tire. It is preferable to make the inclined angle α within a range of from 30° to 50°

The depth g of the stress relieving groove 11 measured along the normal line N–N is preferably 25% to 50% of the total rubber thickness h measured along the normal line N–N. If the groove depth is relatively shallow, the gauge of the base rubber 10 opposed to the groove base is made correspondingly thick. Conversely, if the groove depth is deep, the gauge of the base rubber 10 is made correspondingly thin.

The width of the stress relieving groove 11 is preferably made so wide that the groove does not substantially close even when the tire is subjected to deformation under load when it runs. In Fig. 1, the stress relieving groove 11 is shown at one side only of the tire, but a plurality of relatively narrow grooves may be arranged side by side along the circumference of the tire. It is preferable to make the width of the stress relieving groove (the total width of these grooves if a plurality of stress relieving grooves arranged side by side are provided) within a range of from 2 mm to 6 mm measured along the opening of the groove dependent on the tire side. The width of a stress relieving groove considerably large than the above-mentioned range has no effective function.

The present invention is preferably applied to a tire in which the ratio of the tire sectional height H to the tire maximum width W is 0.5 to 0.8 and the portion of the side edge E of the tread portion T is round, that is a so-called round shoulder tire.

In another embodiment of a pneumatic radial tire having a reduced rolling resistance according to the invention shown in Fig. 2, the independent left and right base rubbers 10 shown in Fig. 1 are connected with each other on the belt layer 3 so as to form a single annular base rubber 10′ interposed between the belt layer 3 and the tread rubber 7. In the present embodiment, that portion of the base rubber 10′ which lies at the side edge E of the tread portion T is interposed between the toroidal carcass 1 and the tread rubber 7, and that portion of the base rubber 10′ which extends from the joint portion 9 between the tread and the side rubber and passes directly below the stress relieving groove 11 towards the bead portion B is made wedge shaped and inserted between the toroidal carcass 1 and the side rubber 6.

In a further embodiment of a pneumatic radial tire having a reduced rolling resistance according to the invention shown in Fig. 3, the side edge of the base rubber 10″ facing the crown centre is made wedge shaped and inserted between the end edge 12 of the belt layer 3 and the toroidal carcass 1.

In order to confirm the effect of the tire constructed as described above according to the invention, test tires each having a size 185/70SR13 were manufactured. The test tire constructed according to the invention was compared with a test tire having the conventional construction with respect to the rolling resistance.

In the test tires, the carcass 1 was composed of two polyester cord layers of 1,500 d/2 and radially arranged. The belt layer 3 was composed of two steel cord plies inclined at 71° with respect to the radial plane and crossed with each other.

The side rubber 6, tread rubber 7, base rubber 10 and stress relieving groove 11 at the shoulder portion of the tire were arranged as shown in Fig. 1. The groove depth g was 3 mm, the total rubber thickness h was 8 mm ($g/h = 37.5\%$) and the groove width was 5 mm. The base rubber gauge directly below the stress relieving groove 11 was 1.5 mm.

In experimental tests, the test tire according to the invention A was compared with a test tire B having a conventional construction. The construction of the test tire according to the invention A and the conventional test tire B is shown in the following Table 1 and the rubber composition of the main portions of these test tires and the physical properties thereof are shown in the following Table 2. In the tire according to the invention A, use was made of a filler rubber F having a dynamic modulus of elasticity of 980 kg/cm^2 and the conventional tire B made use of a filler rubber having a conventional dynamic modulus of elasticity of 180 kg/cm^2.

Table 1

Constitutional Element	Kind of Tire	
	A	B
Stress relieving groove (11)	*o	**o
Base rubber (10)	o	x

Note: In the above table, symbol o means that the tire is provided with the stress relieving groove 11 or base rubber 10. Symbol x means that the tire is not provided with these constitutional elements.
Symbol * means that the groove centre line is inclined from the normal line at an angle α of 40.5°.
Symbol ** means that the groove centre line coincides with the normal line, that is the inclined angle α is zero.

Table 2

			Tread rubber	Side rubber	Base rubber	Rubber filler
Rubber composition (parts by weight)	Natural rubber		—	60	80	100
	Styrene-butadiene copolymer rubber		80	—	—	—
	Polybutadiene rubber		20	40	20	—
	Carbon black	ISAF	75	—	—	—
		HAF	—	—	38	75
		FEF	—	48	—	—
	Phenol resin		—	—	—	24
	Aromatic oil		35	13	4	5
	Sulphur		1.8	2	2.5	6
Physical property (after vulcanization)	Resilience (%)		38	53	70	45
	Loss modulus of elasticity (kg/cm²)		30	8	8	—
	Dynamic modulus of elasticity (kg/cm²)		100	50	—	980

Note)

1. Resilience of a rubber sample of 2 mm × 8 mm × 4 ± 0.1 mm was measur d by a Dunlop tripso resilience tester made by Toyo Seisakusho Co. in Japan at a normal temperature with the aid of a hammer having a weight of 60 g.
2. The loss modulus of elasticity of a strip shaped sample of a width 5 mm × depth 2 mm was obtained by calculation by measuring the loss coefficient and dynamic modulus of elasticity at a temperature of 25°C with a number of oscillations of 50 Hz and dynamic strain of 1% by means of a viscoelastic spectrometer made by Iwamoto Seisakusho Co. in Japan.

Experimental tests have demonstrated the rolling resistance values of the tires as shown in the following Table 3.

Table 3

Speed	Kind of Tire	
	A	B
50 km/h (hour)	3.7 kg (123)	4.8 kg (100)
100 km/h (hour)	4.2 kg (119)	5.2 kg (100)
150 km/h (hour)	7.5 kg (109)	8.2 kg (100)

Similar experimental tests effected on the embodiments of the tires shown in Figs. 2 and 3 have shown satisfactory results which were substantially the same as those described with reference to the embodiment shown in Fig. 1.

As stated hereinbefore, the pneumatic radial tire according to the invention has a reduced rolling resistance while maintaining the properties generally required for such a tire.

CLAIMS

1. A pneumatic radial tire, comprising a toroidal carcass including radially arranged cords, a belt layer superimposed about the crown portion of the carcass and including a plurality of cord layers, each cord being inclined at an angle of from 60° to 80° with respect to the radial plane of the tire and the cords of adjacent cord layers being crossed with each other, a pair of bead cores around which the ends of the toroidal carcass are wound to form turn-up portions, a side rubber outwardly covering each side portion and bead portion of the toroidal carcass, a tread rubber outwardly covering the crown portion of the carcass inclusive of the belt layer and forming a joint portion with each side rubber, relatively thin base rubber disposed directly below each joint portion between the side rubber and the tread rubber and superimposed about the outer surface of the carcass and made integral therewith, the said base rubber having a resilience which is higher than those of the tread rubber and side rubber, and a rubber filler at each bead core disposed between the carcass and its turn-up portion, wherein a stress relieving groove composed of a depression is provided at a position near each joint portion between the side rubber and the tread rubber.

2. A pneumatic radial tire as claimed in Claim 1, wherein the stress relieving groove is generally V-shaped in section and its base is rounded and is arranged such that a straight line bisecting the angle formed between opposed groove sidewalls is inclined at an angle of at most 70° with respect to a normal line passing through the groove base.

3. A pneumatic radial tire as claimed in Claim 1 or 2, wherein the stress relieving groove has a width which is such that the groove does not substantially close even when the tire is subjected to deformation under load when it runs.

4. A pneumatic radial tire as claimed in any of Claims 1 to 3, wherein the stress relieving groove has a depth of from 25% to 50% of the total rubber thickness measured along a normal line passing through the groove base, the groove base being spaced apart from the toroidal carcass by a thin side rubber and the said base rubber.

5. A pneumatic radial tire as claimed in any of Claims 1 to 4, wherein the said base rubber has a resilience of from 60% to 85%.

6. A pneumatic radial tire as claimed in any of Claims 1 to 5, wherein the said base rubber has a loss modulus of elasticity of from 2.0 kg/cm² to 12.0 kg/cm².

7. A pneumatic radial tire as claimed in any of Claims 1 to 6, wherein the said base rubber extends over the belt layer from one side portion to the other side portion.

8. A pneumatic radial tire as claimed in any of Claims 1 to 6, wherein the said base rubber is wedge-shaped and extends from the side portion to the crown portion and is inserted between the belt layer and the toroidal carcass.

9. A pneumatic radial tire as claimed in any of Claims 1 to 7, wherein the said rubber filler

is formed of a hard rubber having a dynamic modulus of elasticity of 300 kg/cm^2 to 1,500 kg/cm^2.

10. A pneumatic radial tire comprising a toroidal carcass including radially arranged cords, a belt layer superimposed about the crown portion of the carcass and including a plurality of cord layers, each cord being inclined at an angle of from 60° to 80° with respect to the radial plane of the tire and each cord of adjacent cord layers being crossed with each other, a bead core around which the lower end of the toroidal carcass is wound to form a turn-up portion, a side rubber outwardly covering a side portion and bead portion of the toroidal carcass, a tread rubber for outwardly covering the crown portion of the carcass inclusive of the belt layer and forming a joint portion with the side rubber, a relatively thin base rubber disposed directly below the joint portion between the side rubber and the tread rubber and superimposed about the outer surface of the carcass and belt layer and made integral therewith, the said base rubber having a resilience which is higher than those of the tread rubber and side rubber, and a rubber filler disposed on the bead core and sandwiched between the carcass and its turn-up portion, wherein a stress relieving groove composed of a depression facing toward the bead rubber is provided at a position near the joint portion between the side rubber and the tread rubber.

11. A pneumatic radial tire according to Claim 1, substantially as herein described with reference to, and as shown in, Fig. 1, Fig. 2 or Fig. 3 of the accompanying drawings.

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